NOT ALL CLUSTER PARTICLES IN THE NASA/JSC COSMIC DUST COLLECTION ARE EXTRATERRESTRIAL. Frans J.M. Rietmeijer, Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, NM 97131, USA.

With data from the NASA/JSC Cosmic Dust Catalogs it is possible to define the petrological properties of chondritic cluster IDPs among a steady background of "unbound" chondritic IDPs [1]. An extraterrestrial source is indicated by a chondritic elemental distribution pattern that is inferred from the relative peak heights of Mg, Al, Si, S, Ca, Fe, and Ni in its EDS spectrum. This chemical signature along with an particle morphology is used to designate individual IDPs as "*C*" (cosmic) or "*C?*". It was recognised that a fraction of the nonspherical chondritic IDPs could be fragments of a larger cluster that broke apart during or just prior to impact onto the collector. Stringent criteria for the identification of cluster IDPs, or clusters in general, are not yet available. This past decade from the Mt. St. Helens (1980 May) to Mt. Pinatubo (1991 June) eruptions witnessed significant volcanic activity that injected dust, including clusters, into the stratosphere**.** For example, collector U2001 contains ten *TCN* (terrestrial contamination natural) clusters. A complete survey of these catalogs showed that the common presence of chondritic clusters wherein the fragments are typically < 19 µm in size [1]. To test the reliability of cluster designation, I performed a detailed transmission electron microscope [TEM] study of particle L2011,12, listed as a fragment of cluster L2011#21. Other IDPs listed as fragments of this cluster include particles L2011,11, -,F1, -,F4 & -,F6 (Dust Courier *11*, 1994). Only aggregate particle L2011F1 with filamentous crystals (whiskers?) is shown in a Cosmic Dust Catalog. Its EDS spectrum supports a chondritic composition.

FRAGMENT L2011,12. This highly irregular glass shard [25 x (8.5-0.3) µm] resembles a sunflower pit. It has an amorphous aluminosilica matrix showing the transition to opal-A and with abundant phyllosilicate nanocrystals. Microphenocrysts include trydimite with tiny zircon and Cr,Pb inclusions, alkali-feldspars, aluminosilicates, Fe-oxide (spheres), low K_2O di,tri-octahedral smectite-kaolinite mixed layer silicates, di-octahedral smectite-illite mixed layer silicates, chlorite and rare TiO_2 and ilmenite. Iron is present as ferric iron. The ubiquitous high-Al, Fe^{3+}-bearing layer silicates resemble those in other volcanic ash particles from the lower stratosphere [2] but they are rare in chondritic IDPs [3]. The Fe-oxides are massive hematite/maghémite spheres and densely-packed patches of maghémite/hematite single-crystals (10-15 nm) and goethite fibers. Particle L2011,12 is a typical volcanic ash shard with evidence for low-temperature aqueous alteration including leaching of Mg, Al and K, and oxidation.

This result prompted me to revisit the TEM data on particle U2015G1 (275 x 140 µm) [4] wherein the trace element contents significantly deviate from CI abundances [5]. The EDS spectrum of this particle, listed as a *C*-type IDP, does not support a chondritic composition [Cosmic Dust Catalog *6(1)*, 1985]. It is designated as a fragment of cluster U2015*A along with L2015G2 (listed as "*?*") and the particles L2015B1-B7 that were incorrectly listed in Dust Courier *11* (1994) as *A2-*A7 (Cosmic Dust Curator, pers. comm., 1996). These seven particles were listed as *TCA?* (terrestrial contamination artificial), *TCN?, (?)* and *C(?)* particles. They include six massive, angular and rounded particles with a high Fe peak, a compact high-Fe cluster of angular grains (-B6) with traces of Al, Si, S, Cl, Cr, Ni, Zn, and two massive angular particles with distinct Si, S, Cl, Ca, and Fe peaks and lesser peaks of Al, Mg, P, Ni, Zn, on a high bremsstrahlungs background. The cluster (3x4 µm) is similar to volcanic clusters at 35 km altitude during 1985 May [6]. The largest massive particle (-B1) is 14x17 µm. Compact cluster -G1 is 25 µm in size and includes two angular shards of ~8 and 14 µm and many smaller grains. The fragments of cluster U2015*A do not show the aggregate morphology of the average chondritic cluster IDP [1], nor show the principal components of the most pristine IDPs [7].

FRAGMENT U2015G1. The ultrafine Fe-oxides in L2011,12 and IDP U2015G1 look very similar. The Al-rich particle U2015G1 was described as a "mechanical mixture of hydrous minerals, iron oxide and silicon oxide" with specific minerals that include talc, saponite, Na-feldspar and fassaite [4]. Fassaite is a Fe^{3+},Al-rich Ca-clinopyroxene with typically > 8 wt% MgO. It is probably unstable when free silica is present. Fassaite occurs in inclusions in terrestrial volcanic rocks, and in hydrated IDPs [8] and in meteorites [9]. The Mg-free fassaite in U2015G1 is a very unusual phase. Fassaite in U2015G1 [4; Table 2] requires 7.1 wt% Fe_2O_3 in order to fit a pyroxene structural formula with $Fe^{2+}/(Fe^{2+}+Fe^{3+}) = 0.5$ (my calculation) which could indicate a coupled substitution $Fe^{2+}(VI) + Si^{4+}(IV) = Fe^{3+}(VI) + Al^{3+}(IV)$. The morphologies and minerals in this particle are strongly reminiscent of volcanic ash. I note that high Al and Fe^{3+} contents characterised the post-crystallisation history of particle L2011,12.

DISCUSSION. These volcanic ash fragments of cluster particles L2011#21 and U2015*A tell their own tale. The fragments in cluster U2015*A have similar sizes than the fragments in the average chondritic cluster IDP [1], but they do not show the typical aggregate IDP texture. The cluster particle U2015*A is the first volcanic cluster identified in the NASA/JSC Cosmic Dust Collection. It is puzzling why the curator accepted the chemistry and morphology of U2015G1 to indicate a "*C*"-type particle. But given this designation, it is unclear why it was accepted as a fragment along with the non-"*C*" fragment of cluster U2015*A. It raises the question that the current criteria for cluster recognition may be ambiguous.

The situation for cluster L2011#21 is different. At least one of its fragments is an 8x6 µm chondritic IDP. This example shows that (*i*) identification of chondritic IDPs on a collector can be incorrect, and (*ii*) unambiguous identification of cluster fragments is not yet possible. It may not always be possible to make a determination based on morphology alone but I submit that particles occurring as single entities > 19 µm on a collector have a low probability to belong to a cluster IDP. By this criterion L2011,12 is eliminated as an extraterrestrial cluster fragment.

Based on data for small area collector (SAC) W7017 the probability of a change overlap between a cluster particle and a single fragment already on a SAC becomes unity for clusters approaching 340 µm, *i.e.* "most large clusters [on a SAC] are likely to include at least one unrelated fragment >1 micron" [9]. This collector has one of the lowest abundances of IDPs between 2-19 µm [*cf*. ref. 1] suggesting that this estimate was probably conservative. These calculations have not been performed for "unbound" volcanic particles. It is also necessary to investigate the probablity of overlap of two clusters on the collector whereby volcanic clusters and cluster IDPs are considered separately.

CONCLUSION. It is not recommended to identify clusters in the NASA/JSC Cosmic Dust Catalogs by a single, or even a few, "representative" stratospheric dust particles. It will be necessary to identify a 'statistically significant' number of putative cluster fragments before it can be accepted as a cluster IDP with volcanic interlopers, or a volcanic cluster with unrelated IDPs. It is critically important to understand the interrelationships among the timing of lower stratospheric collection and stratospheric events. The composition, morphology, and size of particles on the collectors collectively provide first-order discriminants for chondritic clusters and volcanic clusters. Cluster IDPs are important, petrologically well-defined, extraterrestrial materials but their fragments are no "mechanical mixtures". The recognition of volcanic clusters in the collection has some urgency as the past decade of the Cosmic Dust Program coincided with a period of significant global volcanic activity. A statistical analysis of abundances and types of particles from the NASA/JSC Cosmic Dust Catalogs will be useful to fine-tune (preliminary) particle identifications, to investigate particle interrelationships, and to look for trends among the extraterrestrial particles, in particular cluster IDPs.

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